

PHYSICAL AND BIOLOGICAL INVESTIGATIONS IN
THE ULTRAVIOLET PART OF THE
MERCURY VAPOR SPECTRUM

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I. INTRODUCTION

DURING the past two years, we have carried out an extensive study of the behavior of the mercury vapor lamp, with the viewpoint and the needs of the clinic in mind. We introduced the "ultraviolet unit," which produces an average erythema reaction on normal adult skin.¹ We then constructed a simple measuring device consisting of a calcium photoelectric cell in an amplification circuit.² This paper relates our experiments dealing with the problem of dosimetry. In previous publications, the photochemical test as developed by Keller, based on the starch iodine reaction, was recommended for clinical purposes. It seemed to us, however, particularly important to investigate the possibility of establishing, for the ultraviolet emission of this type of lamp, a reproducible unit which could be linked up with the biological effect. In logical order it involves: (1) a study of the relative intensities of the biologically important lines in the mercury vapor spectrum

(3100 to 2500 Ångströms) during one thousand hours of burner life; (2) measurements of the total intensity of the emission of a quartz mercury vapor burner; (3) simultaneous measurements with the photoelectric cell; (4) performance of one of the simpler photochemical tests in order to define its limitations, and (5) controls on a sufficient number of patients for the purpose of establishing an average erythema reaction or a skin tolerance dose.

II. DESCRIPTION OF APPARATUS

In all investigations, a mercury lamp of well-known make has been used. It had a spherical hood of 36 cm. diameter. The construction of the burner was based on that of the mercury rectifier.³ Its transformer was connected to the 110 v.a.c. line. An image of the burner was thrown on the slit of a quartz spectrograph by means of a planoconvex quartz lens. The collimating and camera lens of the spectrograph were planoconvex quartz lenses of 5 cm. aperture and 37.5 cm. focal length

* From the Departments of Roentgenology and Physics, University of Michigan, Ann Arbor, Michigan. Read at the Twentieth Annual Meeting, AMERICAN ROENTGEN RAY SOCIETY, Kansas City, Mo., Sept. 25-28, 1928.

for $\lambda = 6563 \text{ \AA}$. The dispersing system was composed of two 60° Cornu prisms of 4.4 by 7.5 cm. face. This system has a large aperture and a focal surface which is sufficiently plane over the region studied. A micrometer screw with axis parallel to this focal plane carried the thermocouple which could thus be moved at will along the plane. The collimator slit and the thermocouple slit were each 0.5 mm. wide. The thermocouple was an Ag-Bi linear couple with seven junctions of 7 ohms resistance, constructed by Professor H. M. Randall. The thermocouple E.M.F.'s. were measured by a Leeds Northrup high sensitivity galvanometer of 18.8 ohms resistance and a sensitivity of 10^{-7} v per millimeter. Ten ohms resistance in series with the galvanometer and couple gave nearly critical damping. Deflections were read on a scale at a distance of 7 meters.

The same galvanometer with a low resistance shunt was used with a single junction thermocouple to measure the total radiation of the burner. The sensitivity of this system was checked before and after each reading by use of an undervolted lamp operated at a fixed potential and distance. The photoelectric cell was mounted in a light-proof brass box with a shutter and placed at a distance of 50 cm. from the burner. As its dark discharge potential (glow potential) was close to 250 volts, 230 volts D.C. from the storage battery were applied to the cell and checked continuously by a Weston precision voltmeter in parallel. A Leeds Northrup Type P galvanometer (sensitivity 8.3×10^{-10} amperes per millimeter, resistance 1100 ohms) with 10,000 ohms resistance in series gave sufficient deflection for the required readings. As photochemical test, we selected the starch iodine reaction as originally employed by Bering and Meyer,⁴ in its modification by Keller.⁵ A detailed description of the test is found in the first article of this series.¹ It need only be recalled here that the ultraviolet unit or average erythema reaction is the time necessary for the completion of the chemical reaction. The distance between burner and test solution has to be doubled when exposing the human body.

III. EXPERIMENTAL WORK

In order to study the fundamental electrical characteristics of such a burner, a voltmeter and an ammeter with a rheostat for balancing slight variations in the current were arranged in the circuit (Fig. 1). The voltmeter reads, therefore, the potential drop over the ammeter which is

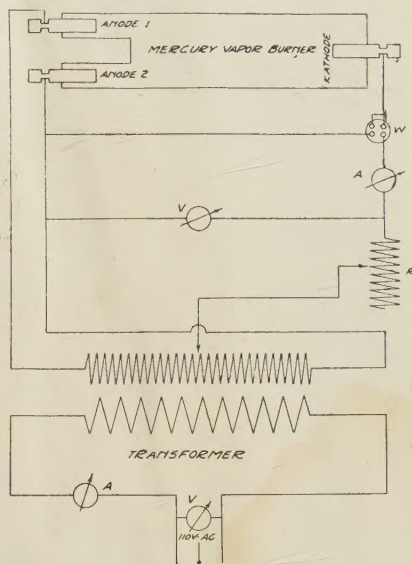


FIG. 1. Schematic diagram of the lamp circuit. Voltmeter (V), ammeter (A), wattmeter (W), and rheostat (R) in the primary and burner circuit.

negligible in this case. For recording the power input, a wattmeter was placed in the burner circuit. The change of potential and current could be recorded every minute from the time of lighting the burner until the point of constancy; it appeared that approximately twenty-five to thirty minutes are required to reach the electrical equilibrium (Fig. 2). This procedure has been repeated and verified numerous times on at least twelve burners. Schall and Alius,⁶ and Hörnicke⁷ have come to the same conclusions. It is at variance with the statement of some manufacturers who believe that only five minutes are required to reach the equilibrium. When comparing the power input and the ultraviolet emission, the same type of voltage-current characteristic as reported by Harrison and Forbes⁸ with a specially constructed burner was encountered; the current drawn

amounted to about 2.75 amperes for all burners over a fairly wide range of potential, the change of which affected the output of the lamp much more than any other factor. Both thermocouple and photoelectric cell record this (Fig. 2); the latter is important clinically because the part of the spectrum in which we are interested

ment built into an apparatus of the type used here should register the potential between one anode and the cathode. This would at least permit the operator to judge when the electrical equilibrium has been reached but no conclusions as to the ultraviolet diation emitted may be drawn.

A total five burners was examined with the methods described above; the results are compiled for one burner (71241) (Table I). Column I gives the age in hours

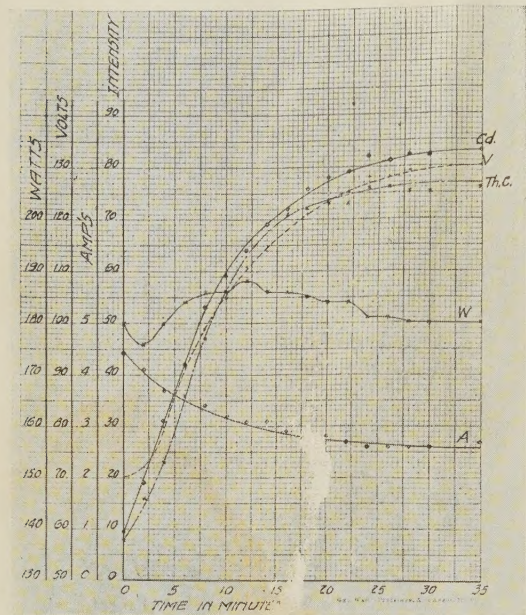


FIG. 2. The changes of potential across the burner (v), the power input (w), the total intensity (Th. C.) and the deflection of the galvanometer (Cd) during the first thirty-five minutes after lighting the burner.

follows the behavior of the potential across the arc. No difference between new and used burners was observed in this respect. It is obvious, therefore, that the control instru-

(A), Column II, the power input in watts (w), Column III, the deflection of the galvanometer connected to the photoelectric cell (Cd), Column IV, the time in minutes and seconds for the photochemical reaction (κ), and Column V, the ratio between the galvanometer deflections when the

TABLE I
BURNER 71241

A	W	Cd	K	Q ST
0	196	10.5	2.3	1.53
25	192	11.0	...	1.46
50	192	10.0	3.0	1.41
100	189	8.5	3.3	1.43
150	185	7.0	3.7	1.40
200	194	7.5	3.25	1.42
250	194	7.0	4.0	1.38
300	196	6.0	4.75	1.12
400	190	7.0	4.3	1.11
500	184	5.0	5.0	0.99
600	190	7.0	5.75	1.14
700	194	6.0	6.3	1.17
800	184	4.5	7.5	1.04
900	174	3.5	8.2	0.80
1000	184	3.5	9.8	0.8
1100	179	3.5	9.4	0.81
1200	191	3.0	12.5	0.9

TABLE II

75257			36627				77191			79940		
A	W	Cd	K	W	Cd	K	W	Cd	K	W	Cd	K
0	192	10.5	2.6	190	10.0	2.45	...	...	....	180	10.5	2.75
50	195	11	2.75	194	9.0	3.0	...	...	....	...	...	...
100	200	8	3.0	194	7.5	3.25	...	...	....	184	9.0	2.50
150	180	7	3.50	196	6.0	3.0	...	...	....	180	9.0	2.75
200	180	5.	5.0	180	7.0	3.0	...	...	....	...	...	...
250	180	6.5	4.0	188	6.0	3.50	194	6.0	3.0	...	...	...
300	176	7.0	4.50	170	7.5	3.25	176	5.0	4.0	190	6.0	3.75
400	190	7.0	4.50	189	7.5	4.0	176	6.0	3.25	...	...	...
500	...	....	....	180	7.0	....	189	5.5	5.0	...	...	...
600	...	....	....	184	5.0	4.0	188	4.0	7.0	196	6.5	5.25
700	...	....	....	190	7.0	4.0	184	4.5	6.0	...	...	...
800	...	....	....	192	6.3	5.50	178	4.0	5.50	186	5.5	6.50
900	...	....	....	...	...	....	180	3.0	7.25	188	3.5	....

thermocouple was placed under the mercury vapor lamp and under the undervolted electric bulb which served as a standard ($\frac{Q}{ST}$). The latter figure is proportional to the total radiation of the lamp. In each instance skin tests on the same part of the body of several adults were carried out

more than that of the other lines. The percentage of error in these measurements is higher for the lines of low intensity because the galvanometer deflection amounted to only 3 mm. or less. The variations in intensity with the distance from the burner were also studied. From Curve Cd in Figure 3, it appears that the

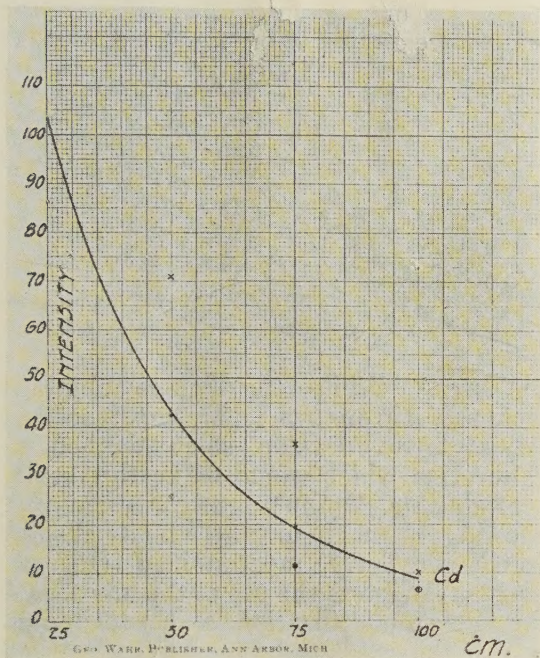


FIG. 3. The changes of the intensity of radiation with the distance from the burner. x = photochemical test; • = cadmium cell; o = calculated by inverse square law.

in order to check the results of the measurements on the biological object. The figures obtained from four other burners will be found in Table II. The reaction time of the Keller test is corrected to 25° c. because like all photochemical reactions, it is dependent upon the temperature. Table III gives comparative data on the lines 3130, 3022, 2967, 2897, 2804, 2650, and 2536 Å, over a period of twelve hundred hours. The intensity of line 3130 was set equal to one hundred. The last column of Table III gives the relative sensitivity (F) of the cadmium cell for each line, while the last horizontal line represents the reading of the photoelectric cell when exposed to the burner. It seems that the relative intensity of 2804, 2650, and 2536 Å drops

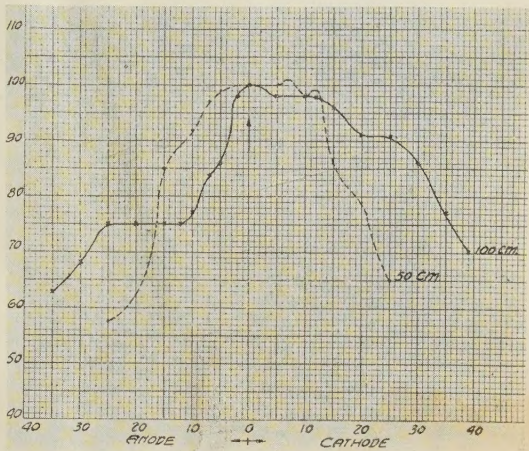


FIG. 4. Total intensity parallel to the burner axis at 50 and 100 cm. distance.

measured intensity of the ultraviolet region recorded by the cadmium cell is not identical with the intensity calculated by means

TABLE III						
Line	New Burner	100 Hrs. Use	After 600 Hrs. Use	After 900 Hrs. Use	After 1200 Hrs. Use	F
3130	100	100	100	100	100	20
3022	32	29	28	25	29	40
2967	21	18	20	14	12	80
2897	6	6	4	6	6	138
2804	6	6	4	3	0	240
2650	12	12	10	7	6	138
2536	15	6	6	7	6	36
Cd	11.5	7.5	6	5.5	3.0	

of the inverse square law. The photochemical test brings this fact out still more strikingly. The calculated and measured values approach each other with increasing distance. Aside from the fact that the burner is not a point source of light, the presence of reflected radiation from the hood explains this observation. Figure 4 demonstrates the distribution of the inten-

sity at 50 and 100 cm. distance from the burner parallel to its axis, taken with the thermocouple and, therefore, showing the variation of the total output. There was no essential difference between new and used burners. The distribution of the total emission in a plane vertical to the axis is given in Figure 5.

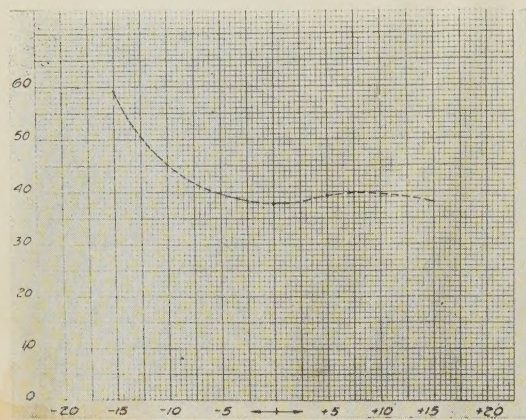


FIG. 5. Intensity perpendicular to the burner axis at 50 cm. distance taken with the thermocouple.

In order to compare the response of the cadmium cell and the photochemical test with that of the skin, a number of experiments with normal and increased potential on new and old burners were performed. The ultraviolet emission of a new burner for which the average erythema time amounted always to about three minutes was measured with a cadmium cell. Other burners were then calibrated on this basis, with a cadmium cell and photochemical test for 50 and 100 cm. distance. Graded exposures of symmetrical parts of the body were checked against the three-minute exposure of a new burner as standard. Since small fields were used as closely side by side as possible, it was relatively simple to select the corresponding reactions without introducing the individual variation.* Tables IV and V show the results.

All these comparative measurements carried out during the past two years have led to the belief that the cadmium photoelectric cell represents today the most simple and reliable device suitable for our

TABLE IV

P	Cd	K	Skin
	10.0	3.0	3
Or	3.0	12.5	9
N	3.3	4.2	3
O			

Column II gives the deflection of the galvanometer connected to the photoelectric cell (Cd). Column III gives the time of the photochemical reaction in minutes (K). The last column gives the time of exposure of the skin. The quotient $\frac{N}{O}$ expresses the ratio between the new and old burner. Number of cases: 11.

TABLE V

v*	Cd†	K‡	Exposure§	Reaction after 6 Hrs.
126	8.5	4.2	4.0	+
158	20.0	2.9	2.0	++
Ratio	2.36	1.45	2.0	over 2.0

* Potential across the arc.

† Deflection of galvanometer of the photoelectric cell.

‡ Time for photochemical test in minutes.

§ Time of exposure in minutes at 50 cm. distance. Number of cases: 7.

purposes.* While the figures obtained were useful in our own laboratory, it seemed advisable to develop some method of calibration which would make the results reproducible. Dorno's sensitivity curve^{9, 10} showing a maximum at about 2800 Å which we have redetermined (Fig. 6, Curve 1) suggests the use of the line 2804 Å for the standardization of the cadmium cell. If the cell is to be used for measuring a range of the ultraviolet spectrum, then, in order to make such a calibration valid, this single line, and all other lines included in this range, should change their intensity with varying potential across the arc or with age of the burner in approximately the same ratio. A study of this question satisfied us that this is the case. As demonstrated in Figure 7, stepping up the secondary potential 25 per cent increased the power input about 30 per cent; the intensity of the examined lines 2.5 times (mean value), and the deflection of the galvanometer connected to the photoelectric cell 2.5 times; decreasing the primary potential by 10 per cent decreased the power input

* Another device has been developed recently by Rajewski.¹¹ He takes advantage of the ionization in a small air chamber due mainly to photoelectrons emitted by a cadmium electrode during exposure to a mercury vapor lamp. The cell window is made of quartz and transmits, therefore, ultraviolet radiation below 2500 Å. We have built a similar chamber of this type which can be connected to most of the roentgen-ray dosimeters on the market. Our preliminary measurements have shown that it will be necessary to adapt the sensitivity curve of the ionization chamber to the erythema curve of the skin.

* In some tests the tintometer method of Schall and Alius (*Strahlentherapie*, 1925, xix, 796) with their original dye solutions was used.

16 per cent, the secondary potential 12 per cent, the intensity of the examined lines to about one-half, and the photoelectric cell reading to one-half (Fig. 6). It was interesting to note that the total emission was increased relatively less at higher potential than the ultraviolet part of the spectrum as recorded by the cadmium

couple and permitting only the one line to pass. The cell current was then measured by a calibrated galvanometer. Thus the current released in the cell by 1 erg/sec. of radiation of line 2804 Å was determined. In this experiment, the standard source of radiation emitting 8.1 erg/sec./cm.² at one meter distance gave a galvanometer

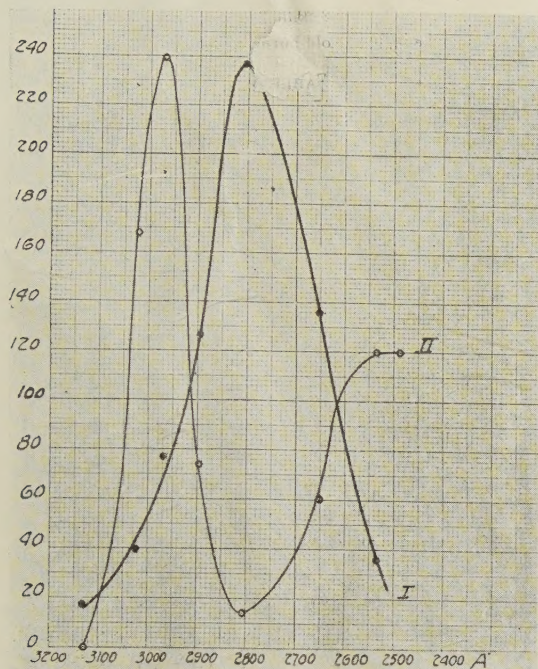


FIG. 6. Sensitivity curve of the Cd photoelectric cell (I) and of the skin (II).

cell, while the opposite held true for the figures obtained with decreased potential.

Table III and Figures 7 and 8 show that the relative intensities of all the lines in the region vary sufficiently alike so that the reaction of the cell to 2804 Å may be used to standardize the cell. This wavelength is chosen because it is the only line which gives a satisfactory response both with the cell and with a thermopile. The following procedure was worked out. A thermopile was calibrated by means of a standard source of radiation (Bureau of Standards) which permitted the measuring of the absolute intensity of the line 2804 Å. Then the cadmium cell was placed in the identical position in the focal plane of the spectrograph, the width of the slit being the same as that of the thermo-

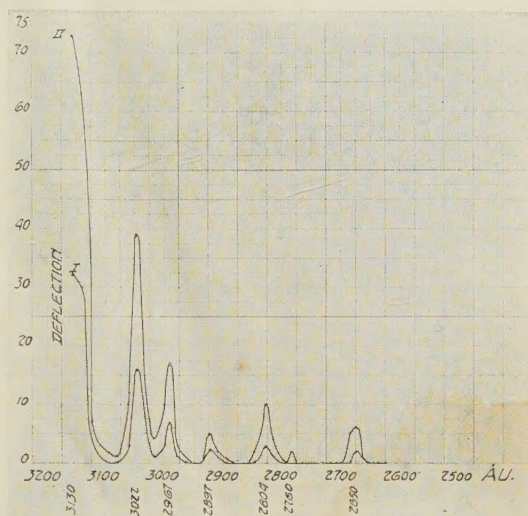


FIG. 7. The relative intensity of the ultraviolet lines between 3130 and 2536 Å at normal (I) and at increased potential (II).

deflection of 44 mm. when falling on the thermopile slit of an area of 0.65 by 16.2 mm. at a distance of one meter. The line 2804 Å of the mercury vapor lamp spectrum gave a deflection of 5 mm., corresponding to 0.099 erg/sec. The same line falling on the cadmium cell gave a galvanometer deflection of 23 mm. It released a photoelectric current of 27.6×10^{-11} amperes.* When the cell was placed at 50 cm. distance measured from the center of the burner to the cadmium film, a photoelectric current of 68.9×10^{-9} amperes was recorded. The slit opening was 1.0×2.5 cm.², 8 cm. above the cadmium surface and with its shorter axis parallel to the burner. The latter had been in operation for about two hundred hours. An exposure of three and one-half minutes at 50 cm. distance produced a medium erythema on adult human skin. These data serve as basis for the calibration of the cadmium cell.

* The same method serves as a control of the sensitivity of an individual cell.

IV. DISCUSSION OF RESULTS

A study of Tables I and II demonstrates the fact that the output of the quartz mercury vapor burner (vacuum A.C. type) decreases rapidly during the first two hundred to three hundred hours of use, in the region below 3100 Å. The figures obtained by means of the cadmium cell

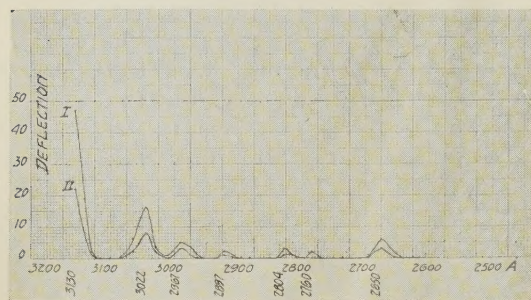


FIG. 8. The relative intensity of the ultraviolet lines between 3130 and 2536 Å at normal (I) and decreased potential (II).

and the photochemical test show fair agreement with the skin reaction. The rate of "aging" then decreases, and after nine hundred to twelve hundred hours, replacement of the burner is usually indicated, since the treatment time is too long for economical work because the emission of short ultraviolet is greatly diminished. The photochemical test and the photoelectric cell do not always run exactly parallel. The emission of the old burner is really more than it is in reality by the photochemical test. This is undoubtedly due in part to the limitations of any photochemical method.* It is apparent that the test becomes more inaccurate with increasing reaction time, if checked by the skin erythema. The latter observation may be made by decreasing intensity through increasing the distance or by using an old burner. It therefore cannot be entirely explained by the statement of Schneiders and Sperti¹² that the decomposition of H_2O_2 seems to be influenced only by radiation below 3600 Å and responds best to short ultraviolet rays.

The comparison of the photochemical, photoelectric, and skin effect offers some interesting deductions as illustrated in

Tables IV and V. From the quotients calculated representing the ratio of new and old burners ($\frac{N}{O}$), it is evident that the cadmium cell reading shows fair agreement with the skin reaction, while the photochemical test gives lower values of the ultraviolet intensity (see Table IV). A similar observation has been made when stepping up the potential (see Table V). The cadmium cell indicates an increase in the ultraviolet part of the spectrum of 2.36 times, the photochemical test only 1.45 times. Skin areas exposed four and two minutes respectively showed a definitely stronger erythema in the field irradiated two minutes with the burner running at high potential. This brings the ratio of skin reaction and photoelectric cell reading in close agreement.

The fact that the inverse square law does not hold for this type of lamp (Fig. 3) makes it inadvisable to calculate the doses at various distances using as initial value the dose known for one distance, particularly if this is below 50 cm. While the decrease of the total intensity as measured by a thermopile follows rather closely the inverse square law at distances more than 50 cm., this is not the case for the short ultraviolet region. It is certain, however, that the difference between the calculated and measured figures, as given by the photochemical test, are exaggerated. It is partly due to the fact that double the distance is used in treatments as during the test. Experiments on the skin have brought this out convincingly. All these observations make advisable the measurement of the intensity for each burner, potential, and treatment distance separately, at least in clinical investigations.

The energy distribution parallel to the axis of the burner at different distances gives definite information regarding the homogeneous exposure of the human body (Figs. 4 and 5). At 50 cm. burner skin distance, a part of 40 cm. length receives a sufficiently even dose; for 100 cm. burner skin distance, the isodose area extends to almost 70 cm. if burner and body axis are parallel (Fig. 4). This allows for a variation in the reaction of ± 15 per cent. Guthmann¹³ obtained similar results. When

* A review of most of these tests is given in Mayer, E., "Clinical Application of Sunlight and Artificial Radiation," Baltimore, 1926, Chapter XIV.

the photoelectric cell was used for these measurements, the readings taken under the cathode part* of the burner seem to show more ultraviolet rays of short wave length than the remaining part of the arc, as high as 30 per cent more than the center. The total intensity does not show, however, such high variations under the same measuring conditions. Again it can be stated that new and used burners behave alike. By reversing the position of the cell and, therefore, changing the part of the cadmium film exposed to the light, it became evident that different parts of the cadmium layer give a different emission. The cell must be left in exactly the same position in order to get comparable results. The intensity change perpendicular to the burner axis is much smaller in total emission as measured by the thermocouple (Fig. 5). Assuming a diameter of 30-40 cm. between the axillae as average, an even dose would be delivered at 50 cm. burner skin distance. All these calculations do not take into consideration the varying sensitivity of the skin in different parts of the human body.

An attempt to establish a physical dose unit and to correlate that unit with the biological effect encounters serious difficulties. A number of investigators have offered suggestions, for instance, Eidinow,¹⁴ Hill and Eidinow,¹⁵ Griffith and Taylor,^{16,17} Coblentz,¹⁸ Schultz,¹⁹ and Anderson and Robinson.²⁰ Hill and Eidinow worked out a unit (IK) based on the killing effect of short ultraviolet rays on *Paramecium*. Three IK units produced a definite erythema in the majority of cases. Griffith and Taylor adopted an arbitrary unit corresponding to the drop of their electroscope connected to the quartz cadmium cell in a given time. This quartz cell transmits, however, ultraviolet rays below 2500 Å and must therefore read different values than those corresponding to the skin effect. On the other hand, the cadmium cell in uviol glass has its maximum at 2800 Å, which is lower than the skin maximum at about 3000 Å. According to

Hausser's²¹ latest publication, there is a second maximum for the skin erythema at 2536 Å (Fig. 2, Curve II). In that case the sensitivity curve of the cadmium cell should run almost parallel to that of the skin. An objection voiced by Rüttenauer²² does not concern us in this investigation; he requests the spectral energy curve in addition to the cadmium cell reading if different sources of light are to be compared. Coblentz and Schultz selected an absolute unit, i.e., the gram calorie per centimeter² per minute. Coblentz suggests 0.01 gram calorie per square centimeter per minute of the radiation of that part of the sun spectrum obstructed by window glass. According to Schultz, 0.08 gram calorie per square centimeter corresponds to a medium erythema dose. Anderson and Robinson have incorporated an absolute unit in a photochemical reaction; they measured the decomposition of an oxalic acid solution for a number of wave lengths in the ultraviolet region, the absolute energy of which was defined in erg per second. Anderson and Gordon²³ recently designed a fluorescent ultraviolet photometer which measures the quality of ultraviolet radiation in various parts of the spectrum by using filters. It has been calibrated by the authors in ergs, and a calibration chart furnished with each instrument.

There is no doubt that none of these methods is ideal. Units are chosen at will, and although they serve the purpose well in the laboratory where they have been developed, no general comparison of results is possible on a common basis. Photochemical reactions are either inaccurate or too complicated. They can, of course, be perfected in a scientific laboratory (see, for instance, Field and Baas-Becking)²⁴ but they are not so satisfactory in practice. It must be admitted also that the cadmium cell is not perfect, but it undoubtedly offers the best possibility at the present time. Its calibration can be carried out, and for practical purposes a simple unit making use of an amplification circuit has been constructed by Huxford and one of us.² The correlation between the recorded energy and the biological effect is easily established. The degree of ery-

* Some observers (Koepe and Lauber, *Arch. f. Kinderheilk.*, 1928, lxxiv, 1) found more emission under the anode; they used, however, a different method, namely, the degree of hemolysis in an erythrocyte solution. Schall and Alius (*Strahlentherapie*, 1927, xxvi, 651), on the other hand, measured a higher intensity under the cathode.

thema should be left to the individual clinician. There is no doubt that very few agree on the conception of a skin tolerance dose. For statistical purposes a mean value can be instituted based on a large number of cases as has been done at the University Hospital in Ann Arbor. The energy measured by a certain deflection of a galvanometer connected to the calibrated cadmium cell and corresponding to a known quantity of electricity may be called one ultraviolet unit provided it will produce a mild erythema on normal adult human skin. We defined this dose by the following factors:*

Burner-cadmium film distance..... 50 cm.
 Cell window (short axis parallel to burner)..... 1.0×2.5 cm.²
 (8 cm. above cadmium surface and under center of burner)
 Released photoelectric quantity in the cell (equivalent to the ultraviolet unit) the same as that quantity released by 6000 erg of $\lambda = 2804$ Å.

This renders the dose reproducible and permits the calibration of other cadmium photoelectric cells in this unit. The figures given for the so-called erythema dose should be regarded as a "statistical mean value" in analogy to the same procedure in roentgen-ray therapy (Pohle and Barnes²⁵).

V. SUMMARY

(1) A study has been made of the spectral energy characteristics of the mercury vapor lamp. A vacuum type burner run at 110 volts A.C. was used in all investigations. Measurements of the variation of the relative intensity of the lines, 3130, 3022, 2967, 2897, 2804, 2650, and 2536 Å under varying conditions, i.e., age of burner and operation are reported.

(2) The ultraviolet emission has also been measured by a cadmium photoelectric cell in uviole glass, by the starch iodine test, and by the skin erythema. It may be concluded from these investigations that the cadmium cell gives a satisfactory reading of the erythema producing ultraviolet part of the mercury vapor spectrum.

(3) A method is proposed by which the calibration of a photoelectric cell in absolute units can be carried out. This permits

checking the sensitivity of an individual cell and calibrating other cadmium cells in the same units. The correlation between this absolute unit and the biological effect (skin erythema) has been established.

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* For detailed data see page 343.

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DISCUSSION

DR. P. M. HICKEY, Ann Arbor, Mich. I think this paper reminds us of a presentation that was made at the time Mr. Snook brought forth the milliammeter. We were accustomed to turn our tubes on, and guess at the results. Then when Mr. Snook came along and told us we could use the milliammeter, we began to get the idea of the energy output of our tubes.

So I think the introduction of this measuring device which Dr. Pohle has just described marks an era in the use of ultraviolet radiation because without some means of measuring and comparing the output of these different lamps, the clinician has to go purely by rule of thumb. This instrument gives a means of comparison of different mercury vapor lamps and the comparison of the efficiency of one particular lamp during different periods of activity. I therefore think it marks a very important step in the standardization of the ultraviolet dose.

PROF. RALPH A. SAWYER, Ann Arbor, Mich. I want to make a few comments on this paper from the point of view of a physicist. There are one or two things with regard to the use of the cadmium cell for the calibration of the quartz mercury vapor lamp which, I believe, should be mentioned. I would like to say that the cadmium cell in the uviol glass has been used for many years by Dorno for the measurement of the intensity of the ultraviolet radiation from the sun. In the use of the cadmium cell for the measurement of the output of the quartz mercury vapor lamp, a different problem arises. The mercury vapor lamp, in contrast to the sun, emits a discontinuous spectrum, while the sun emits a continuous spectrum; the lamp also emits varying wave lengths which vary

considerably in intensity under different conditions of emission.

The question we have to ask ourselves is whether or not under the conditions of emissions which we meet in the clinical use of the lamp, the various lines which it emits will vary in intensity all in the same way, since the cadmium cell is exceedingly selective to wave length in its response.

Our measurements show, which I, myself, did not expect, that the various lines in the erythema producing region of the spectrum all behave in nearly enough the same way under the varying conditions of age of the burner and operating conditions so that it is perfectly safe to use the cadmium cell to measure the ultraviolet output of the lamp. The cadmium cell does certainly rate the ultraviolet output of the quartz lamp in some sort of unit.

The question then arises whether that unit is a unit which is proportional to the erythema producing ultraviolet dose, a thing we all want to know. The cadmium cell is very selective to wave length, and the skin is also very selective in its receptiveness to the ultraviolet wave length.

The two curves which we see in Figure 6 are certainly very similar. They do not coincide. There is another point, and that is with varying intensity of light, the response of the cadmium cell is proportional to intensity throughout the wave length range while, if we can believe the recent work of Hausser and Vahle, the response of the skin to varying intensities of light for different wave lengths, while the response is proportional to the intensity, the proportionality factor is very different for different wave lengths. That means I think, that it is impossible to hope for any measuring device which will give us precisely the response of the skin to ultraviolet radiation. The only answer as to whether a certain device is suitable or not is the clinical answer, and I hope it will please you to hear a mere physicist, who is interested in measurements, say that.

I think that the clinical measurements Dr. Pohle has carried out in the hospital over a period of years show that the cadmium cell with the uviol glass bulb is a perfectly satisfactory device for measuring the ultraviolet erythema producing efficiency of the mercury vapor lamp in quartz glass.

There is just one other thing to say, the question of the absolute rating of the lamp. The method of rating the lamp in absolute units which we have introduced here depends on the permanence and reproducibility of the cell. I think there is no question of the permanence of the cell if not abused. As to its reproducibility, we have repeated in our laboratory the

curves of the sensitivity of the cell and checked precisely the curves which have been given by Dorno and also by other investigators.

Absolute measurements of the kind we have made here are difficult and can be made only in a precision laboratory. The use of the cadmium cell itself, I believe, is almost foolproof. No filters are required and no chemical manipulation is necessary.

When you have a calibrated cell set up in its circuit, it comes down to the reading of one instrument, which can be done in a couple of minutes, and I should like to point out just one thing about the need of rating such a lamp.

Our measurements show that a variation of 1 per cent in the input voltage on one of these lamps causes a variation of 5 per cent in the ultraviolet output. If any of you, who have to deal with commercial city circuits, will put a voltmeter on a circuit, you will quickly find, unless you are exceptionally fortunate, that the voltage variation with which you have to deal may be as much as 5 per cent, or even 10 per cent under certain conditions, meaning a variation of the ultraviolet output of your lamp of 50 per cent, to say nothing of the rapid depreciation with age which must be continually checked.

